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monthly organ, published in Paris, now in its second year, *Thérapeutique Intégrale.* Its guiding spirit is Dr. G. Encausse, known to modern alchemists as Papus, the author of many treatises on the ancient pseudo-science. As apostles and forerunners of this system he claims Hippocrates, Paracelsus, Hahnemann.

All this would be very amusing if it were not sad—sad to find that educated men can so degrade their knowledge of chemistry, physiology and medicine; sad to think of the conceptions of these sciences formed by persons subject to the influence of these 'lewd impostors;' sad to think of the suffering that ensues for lack of proper treatment; sad to think of the unscrupulous immorality of those willing to trifle with human life for selfish gain. One is inclined to cry with Massinger:

> "Out you imposters,
> Quack salving, cheating montebanks, your skill
> Is to make sound men sick, and sick men kill."

H. CARRINGTON BOLTON.

THE DEVELOPMENT OF ELECTRICAL SCIENCE.

II.

THE subject of telegraphy is closely associated with the present excellent system of electrical measurements and with the invention of many of our most delicate measuring instruments. As the applications of electricity increased there gradually grew up a new branch of engineering, a branch, however, in which the foot-rule, pound-weight, chronometer and thermometer were not sufficient. Other standards of measurement were required, in order that quantities could be gauged and consistent work done. The way to connect the measurements of the new quantities with the units already in use in dynamics had been pointed out by Gauss and others, and at the suggestion of Thomson the British Association appointed a committee in 1861 to determine the best standard of electrical resistance. This led to an unexpected amount of work not only on a standard of resistance, but also on the general subject of electrical measurement. The committee regretted, at the end of the first year, that it could not give a final report, but hoped that the inherent difficulty and importance of the subject would sufficiently account for the delay. It can hardly be said that the final report has yet been forthcoming, as a committee with some of the original members in it still exists and reports regularly every year on valuable work done by it. The committee worked energetically for a number of years, not only on the standard of resistance, but on those of current, electro-motive force and capacity. It incidentally supplied a great deal of quantitative data on a number of subjects and particularly as to the permanence of alloys, the variation of their resistance with temperature as depending on their composition and so forth. In looking over the results of the early work of the British Association committee one is apt to indulge in adverse criticism. It is hard for many of the younger workers to appreciate the difficulties which are met in a first attempt. It would be equally just to congratulate ourselves that we have better marksmen to-day than there were fifty years ago, without making allowance for the modern rifle.

The first absolute determination of resistance was probably that made by Kirchhoff about fifty years ago. Weber published his method in 1852, and then came the B. A. determination by Maxwell, Stewart and Jenkins in 1863. Neither of these were very exact, but they paved the way for the splendid exhibitions of experimental skill which followed. Among those to whom we are most indebted for this later work may be mentioned Kohlrausch, Rayleigh, Glazebrook, Rowland, Wiedemann, Mascart, etc. The greatest step in advance in recent years

has been the invention of the revolving disc method by Lorenz, of Copenhagen, and its subsequent improvement and application by himself and by J. V. Jones. The determinations made by the latter by this method are probably almost absolutely correct.

A subject which has attracted much attention comes in incidentally here, namely, the electro-magnetic theory of light propagation suggested by Maxwell. According to this theory the ratio of the electro-magnetic unit of quantity of electricity to the electrostatic unit ought to be the same as the velocity of light. In 1868 a determination of this ratio was made by McKichan under Lord Kelvin's direction, and gave close agreement with the theory. Since that time determinations have been made by various methods by Maxwell, Shida, Ayrtin & Perry, J. J. Thomson, Rosa, Lodge, Glazebrook and others, with the result that the ratio of the two units does not differ from the velocity of light by more than the probable error of observation. The work here referred to may not appear to be very directly associated with the determination of standards of measurements. It is, however, one of the investigations which has been made possible by the work of the B. A. committee in the production of instruments of precision. Prominent among these instruments stands the Kelvin electrometers, and particularly the absolute electrometer which was described in the report of the B. A. committee for 1867.

Another subject of great interest in itself and in connection with Maxwell's theory is that of the specific inductive capacity of dielectrics. Experiments on this subject were made by Faraday, but comparatively little was done before 1870, in which year an excellent paper was communicated to the Royal Society, by Gibson and Barclay, on the specific inductive capacity of paraffin. Since that time much good work has been done by Boltzman, Hopkinson, Quincke, Silow, Klemencic, Negreáno and others. The theoretical importance of these experiments is due to the fact, that, according to Maxwell's theory, the specific inductive capacity of non-magnetic dielectrics should be proportioned to the squares of their indices of refraction. A wonderful verification of Maxwell's theory was carried out only some ten years ago by Hertz, who showed not only that electrical waves exist, but also how to measure their wave length and period. We have in these experiments splendid illustrations of the oscillatory discharge referred to above, as discovered by Henry and predicted by Thomson, and as a result several new ways of determining electrical quantities have been developed. It is now possible, for example, to compare the capacity of condensers by means of oscillatory currents of exceedingly short periods, and thus to determine the dielectric constants of many materials to which the older methods were not easily applicable.

It is somewhat difficult to decide where to place a reference to the recent discovery of Röntgen and its development in photography, but probably it comes in well here. Just how to apply Maxwell's equation to Röntgen rays is not yet quite clear, but there is no doubt as to the great importance of the discovery.

As an outcome of all this activity in the determination of standards and in the absolute measurements of the electrical properties of materials, combined with the great commercial demand produced by the introduction of dynamo-machinery, we have now many excellent instruments at our disposal for absolute measurement and suitable either for practical applications or for the most refined laboratory work. For the production of these we are indebted to a host of inventors, prominent among whom may be mentioned Lord Kelvin, Lord Ray-

leigh, Ayrton & Perry, Mather, Swinburne, Cardew and Weston.

Magneto-electric and dynamo-electric generators and motors have now become so common that we are apt to forget that their introduction on an extensive scale has only taken a few years. Faraday's disc dynamo was, as has already been stated, produced in 1831, and a machine for generating electricity was made by Pixii in the following year. Pixii's machine consisted of a horseshoe permanent magnet which was rotated in such a way that its poles passed alternately in front of the poles of a similar electro-magnet. An alternating current was thus induced in the circuit which included the coils of the electro-magnet.

This machine was improved by Clarke, who removed the coils and put a commutator on the axis. Other machines were made or suggested by various physicists, and an important observation, which has since been frequently overlooked, was made at this time by Jacobi, who pointed out the importance of making the cores of the coils short. Sturgeon, in 1835, made a dynamo with a shuttle-shaped armature; a similar form has long been identified with the name of Siemens. Woolrich made a multipolar magneto machine in 1841 for electroplating, and Wheatstone about this time produced his small multipolar magneto, long used for telegraph purposes. In 1845 Wheatstone and Cooke patented the use of electro-magnets in place of the permanent magnets, and Brett suggested, in 1848, that the current from the machine might be made to pass round a coil surrounding the magnet and thus increase its strength. A similar suggestion was independently made in 1851 by Sinsteden. In 1849 Pulvermacher proposed the use of thin laminæ of iron for the cores of the magnet, a proposition which has since, but probably for a different reason, been almost universally adopted. Sinsteden used iron wire cores and made a number of experiments on the effect of varying the pole face. About this time another class of machines were proposed by Ritchie, Page and Dujardin. In these machines both the magnets and the coils were to be stationary, but the magnetism was to be varied by revolving soft iron pieces in front of the poles. Modern representatives of these machines are to be found in the dynamos of Kingdon, Stanley and others. All the machines up to this time had been of very small dimensions In 1849 Nollet began the construction of an alternating machine on a larger scale, but died before it was completed. Machines of Nollet's type were afterwards made by Holmes and by the Compagnie l' Alliance of Paris, the latter being called the Alliance machine. These machines were used for lighthouse purposes. Holmes's earlier machines were continuous current, but later he left out the commutator, and still later again introduced it on part of the coils for the purpose of obtaining current to excite his field magnets. This latter plan was introduced after the self-exciting principle had been introduced by Siemens and Wheatstone. A remarkable machine historically was patented in 1848 by Hjorth. In this machine a combination of the permanent and electro-magnet was used, the first to give magnetism enough to produce a current with which to excite the other. A similar idea was developed fifteen years later by Wilde with the difference that the permanent magnet part was a separate machine. The idea of using part of the current from the armature to excite or partially excite the field magnets was at this time in the minds of a number of workers, and some remarkable machines were patented by the brothers Varley, one of which containing both a shunt and a series winding has been held by some to anticipate the compound winding now in use. In 1867 it seems to have occurred independently to Wheatstone and E. Werner

Siemens that the permanent magnet part of the Hjorth and Wilde machines might be dispensed with, the resident magnetism being used to start the action. Siemens gave the name dynamo-electric machine to this type and it has stuck. In order to diminish the fluctuations in the strength of the current during one revolution of the armature Pacinotti devised his multi-grooved armature in 1864. This machine did not receive the notice it deserved for a number of years, and in the meantime Gramme produced his smooth ring armature in 1870. Gramme's machine was soon recognized as being of great merit, and its gradual introduction gave rise to increased activity. In 1873 the Hefner-Alteneck improvements on the Siemens armature were introduced and in the remaining 70's quite a number of forms of dynamo were invented, the Loutin type introduced in 1875 with improvement in subsequent years being one of the best. The early 80's saw tremendous activity; the patent offices in Europe and America were flooded with inventions of various types of dynamos and motors, of lamps for electric lighting and so forth. It is curious how few of those machines have stood the test of time and how well the old types of Pacinotti, Gramme, Siemens-Alteneck and Loutin in some one of their modifications hold the field. Great progress has been made in the last fifteen years. Machines have assumed enormous proportions and the number of branches of industry to which they have been applied is now very large. Much has been learned during this time, particularly with regard to alternating currents and their application to the transmission of power, the introduction of Multiphase systems being of considerable importance in this connection. In the direction of high potential and great frequency the work of E. Thomson and Tesla is of great interest.

Of the application of electricity to the production of light and heat little need be said in this connection. The difficulties to be overcome were largely mechanical, and with the progress made we are all familiar.

As regards primary batteries there has been, of course, as we all know, considerable progress since the time of Volta. The number of forms brought into use has been enormous and they have been important in increasing our knowledge of the relative electro-motive force of various combinations and in their bearing on chemical knowledge. It can hardly be said that an ideal primary battery has yet been obtained, when we look at the subject from a commercial point of view. Although the subject is not very much to the front at present, however, it is destined to come again, and will, I have no doubt, be, in a comparatively short time, one of our leading industries.

The work of Planté and of Faure and others on secondary batteries has been of great value commercially. They gave rise to several chemical problems, but the main difficulty here also has been of a mechanical kind, and they have not added much to the knowledge of electrical laws.

The transformation of alternating currents from high to low potential and *vice versa*, by means of what are commonly called transformers, has shown another remarkable development of Faraday's discovery of induced currents. The application of transformers has made it possible to distribute electrical energy over large areas in a moderately economical manner, and incidentally has led to considerable increase in the knowledge of the magnetic properties of iron.

One of the most important of the applications of electricity is that of electrochemistry. The chemical action of the electric spark was noticed by van Groest and Dieman in 1739 in the decomposition of water.

Beccari, about the middle of the 18th century, obtained metals from oxides through which the spark had passed, and in 1778 Priestley noted the production of an acid gas when the electric spark was passed through air. Similar experiments were made by Cavendish and Van Marum on decomposed ammonia. It is not, however, until after the discovery of the voltaic cell that the subject of electrolysis really begins. I have already referred to the discovery of Nicholson and Carlisle in 1800, and the subsequent work of Davy and of Faraday. The peculiar phenomenon of the appearance of separated elements only at the end plates in the electrolytic cell led to considerable speculation, and was explained by Grothuss on the supposition that the molecules separated into two parts, one positively and the other negatively electrified, and that these parts formed a chain between the plates along which chemical action traveled by a continual interchange of mates, the end parts going to the plates. This theory was held for many years, and is still to be found in some text-books. Faraday's work is by far the most valuable of the early contributions to the subject. He gave the following laws:

The amount of chemical decomposition in electrolysis is proportional to the current and the time of its action.

The mass of an ion liberated by a definite quantity of electricity is directly proportional to its chemical equivalent weight.

The quantity of electricity which is required to decompose a certain amount of an electrolyte is equal to the quantity which would be produced by recombining the separated ions in a battery.

These laws are all of the greatest importance and the last one clearly points out the reversibility of the electrical process. By forcing a current through an electrolyte it is decomposed and the mutual potential energy of the components consequently increased. By allowing the components to recombine in a battery the mutual potential energy is reduced and a current of electricity is the result. An excellent illustration of this action is exhibited by the secondary battery.

In 1857 Clausius gave a theory of electrolysis and at the same time reviewed the weaknesses of the hypotheses of Grothuss and others. Clausius assumes that the molecules of the liquid are in continual motion; that impacts frequently occur which produce temporary dissociation, leaving atomic groups charged with opposite electricities, and that during these separations any directive agency, such as an E. M. F., is able to cause a motion of these atoms in opposite directions. This is probably the first indication of the idea of the purely directive character of the applied electromotive force taking advantage of dissociation to produce chemical separation.

The energy side of the problem now began to attract attention and the development of what may be called the thermodynamics of electro-chemistry began. Among the most prominent workers in this field have been Joule, Helmholtz, Gibbs, Kelvin, Boscha and Favre.

In 1853 Hittorf made quantitative determination of the change of concentration near the electrodes when a current is passed through a solution. This work is of historical interest because it formed practically the starting point for what may be called the modern view of electrolysis. Hittorf's experiments extended over several years and served practically to establish the theory of the migration of the ions in the solution. Hittorf communicated the following laws:

The change in concentration due to current is determined by the motion which the ions have in the unchanged solution.

The unlike ions must have different velocities to produce such change of concentration.

The numbers which express ionic veloci-

ties mean the relative distance through which the ions move between the salt molecules, or express their relative velocities in reference to the solution, the change in concentration being a function of the relative ionic velocities.

Hittorf's analyses enabled him to give numerical values to these relative velocities. The experiments of Nernst, Loeb and others have extended Hittorf's results, and have shown that in dilute solutions the relative velocities of the ions are independent of the difference of potential between the electrodes and are only slightly, if at all, influenced by temperature. Hittorf pointed out that a knowledge of the conductivity of electrolytes should give valuable information in reference to the nature of electrolytic action. A great deal of work has been done in this direction by Horsford, Wiedemann, Beetz, the Kohlrauschs and others. The most notable, perhaps, was the work of P. Kohlrausch, who devised a method of measurement, using alternating current by which results of high accuracy were obtained. Kohlrausch's results give the sum of the ionic velocities, and thus, combined with the results of Hittorf on change of concentration, which gave the ratios, the absolute velocity can be obtained. It appears from these results that the velocity of the ion in very dilute solutions depends only on its own nature and not upon the nature of the other ions with which it may be associated. For example, the velocity of the chlorine ion is the same when determined from solutions of KCl, NaCl or HCl. The important general law has also been found that the conductivities of neutral salts are additively made up of two values, one dependent on the positive, the other upon the negative ion. If, then, the velocities of the ions themselves be known the conductivity of a salt may be calculated. The results of Kohlrausch received strong confirmation from some very ingenious experiments by Lodge and Whetham in which the migration of the ions was made to produce a change of color in the solution, and could thus be directly observed.

In 1887 the theory was advanced by Arrhenius and Ostwald that dissociation is directly effected by solution or fusion and that in very dilute solutions the dissociation is practically complete. Arrhenius holds that the ions carry charges of electricity, positive or negative, dependent upon their nature, but of equal quantity in every ion. The remaining part of the theory is similar to that of Clausius and others. According to this theory the ratio of electric conductivities for different densities of solution gives a measure of the relative dissociation or ionization. If the act of solution effects the dissociation necessary to admit of electrolysis chemically pure substances ought not to be decomposed by the electric current, and this is found to be the case. It is curious that two substances like hydrochloric acid and water, which separately are insulators, should, when mixed, conduct readily, and that practically only one of them should be decomposed. This, however, is only one of the many problems still to be solved. Another question is how do the ions obtain their electric charge? Still another, what is the nature of the force which causes ionization? There are many more.

When we turn to the commercial application of electro-chemistry we are met with astonishing evidence of activity. Only twenty years ago there was comparatively little evidence of the importance of this branch of applied electricity. At the electrical exhibition in 1881 electro-chemistry was apparently of comparatively little prominence. A factory which could produce a few hundreds of tons of copper electrolytically was considered a wonder. The production of thousands of tons a

month is beginning to be looked upon as commonplace. There is scarcely a metal which cannot be deposited electrolytically with comparative ease and the prices of some of the rarer metals is going down rapidly. Zinc used to be considered a difficult metal to deposit successfully. It is now produced in some of the Australian mines in almost a pure state from refractory ores at the rate of thousands of tons per annum. Similarly the old method of galvanizing is rapidly disappearing and electro-deposition is taking its place and this metal is now so deposited on the hulls of ships, on anchors and other smaller articles cheaply and perfectly. A new industry has practically sprung up and there is every indication that the technical chemist of the near future will have to take an inferior place unless he be also well versed in electricity and electrical appliances. This branch of applied science is revolutionizing many things. It has within a few years produced an enormous improvement in our magazine illustrations, and has, at the same time, reduced the cost of this kind of literature and of atlases and charts enormously. Electro-chemistry is now used on a large scale for the production of chlorate of potash, bleaching materials, alkalies, coloring matters, antiseptics, like iodoform, anæsthetics, like chloroform, etc. In fact, it is getting to be difficult even to enumerate the manufactures in which it is used. It has revolutionized the extraction of gold, and plants of enormous capacity are now in use in some of the gold fields, the poorest ores and tailings being made to yield up almost the last trace of the precious metal. The production of ozone by the ton, the purification of sewage and the sterilization of water are all accomplished facts.

Some progress has even been made in the introduction of chemicals through animal tissue by electrolysis or cataphoresis, and Röntgen has shown us how to see through the body.

Then, again, we have got the electric furnace, and with it the power to fuse almost the most refractory substances. In this way aluminum is now produced at a few cents a pound, whereas most of us remember when its price had to be reckoned in hundreds of dollars. In a similar way phosphorous is now produced on a large scale, as are also various carbides, carborundum, acetylene, etc.

It is impossible to look back over the history of electricity and its applications and notice the apparent geometric ratio in which advances are being made, and not to speculate on what a giant this science is going to become in another quarter of a century. Undoubtedly no one can study this one branch of science without being persuaded of the great value of scientific work for the advancement of human enterprise.

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*A PROPOSED BUILDING FOR THE SCIENTIFIC ALLIANCE OF NEW YORK.**

THE Scientific Alliance is the outgrowth of several conferences of commissioners from all of the societies now included in the Alliance (except the Entomological Society, which was not then in existence, and also of the New York Branch of the Archæological Institute of America, which, however, did not enter the final organization), called by a committee appointed by the New York Academy of Sciences, in February, 1891, 'to consider what methods might be adopted for mutual benefit and support.' The first meeting of the Commission was held at the American Museum of Natural History on March 11, 1891, and amongst the subjects discussed was 'the desirability

*Report of the Building Committee, C. F. Cox, Chairman, to the Council of the Scientific Alliance of New York.